Bonneville Power Administration
Fish and Wildlife Program FY99 Proposal Form

Section 1. General administrative information

Physiological assessment of wild and hatchery juvenile salmonids

Bonneville project number, if an ongoing project 9202200

Business name of agency, institution or organization requesting funding
National Marine Fisheries Service, NOAA, DOC

Business acronym (if appropriate) NMFS

Proposal contact person or principal investigator:

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Subcontractors.

Organization	Mailing Address	City, ST Zip	Contact Name
Oregon State University, Cooperative Fishery Research Unit	104 Nash Hall	Corvallis, OR 97331	Carl B. Schreck
University of Washington, School of Fisheries	Box 355100	Seattle, WA 98195	Walton W. Dickhoff

List one subcontractor per row; to add more rows, press Alt-Insert from within this table

NPPC Program Measure Number(s) which this project addresses.
Measure 7.2D1,3,5; 7.3B.2,6,7,; 7.4K.1; 8.3c

NMFS Biological Opinion Number(s) which this project addresses.

Other planning document references.

If the project type is AWatershed≅ (see Section 2), reference any demonstrable support from affected agencies, tribes, local watershed groups, and public and/or private landowners, and cite available documentation.

Snake River Recovery Plan Tasks 4.3 and 4.4

Subbasin.

Mainstem, Yakima

Short description.

The overall goal of this research is to reduce negative impacts of hatchery salmon on wild salmon and evaluate supplementation by 1) improving the smolt quality and smolt-to-adult recovery (SAR) of fish reared in hatcheries, and 2) producing a more wild-type hatchery smolt in supplementation programs. The experimental objectives of our on-going and proposed work include improving smolt-to-adult survival of the Columbia River terminal fishery (CCEDC, ODFW, WDFW) by growth rate manipulation (enhancing spring growth rate) of juvenile spring chinook salmon before release. A second major element of our research is to characterize the physiology of salmon reared under conventional and natural-rearing systems in the supplementation program of the Cle Elum Hatchery (Yakama Indian Nation and WDFW).

Section 2. Key words

Mark	Programmatic Categories	Mark	Activities	Mark	Project Types
__*__	Anadromous fish	_____	Construction	_____	Watershed
_____	Resident fish	_____	O & M	_____	Biodiversity/genetics
_____	Wildlife	_____	Production	_____	Population dynamics
_____	Oceans/estuaries	__X__	Research	_____	Ecosystems
_____	Climate	__*__	Monitoring/eval.	_____	Flow/survival
_____	Other	_____	Resource mgmt	_____	Fish disease
		_____	Planning/admin.	__*__	Supplementation
		_____	Enforcement	_____	Wildlife habitat en-
		_____	Acquisitions		hancement/restoration

Other keywords.

smoltification, hatchery reform, hatchery-wild interaction

Section 3. Relationships to other Bonneville projects

Project #	Project title/description	Nature of relationship
9306000	Columbia River Terminal Fisheries Research Project	Collaborate on experimental design and analysis; monitor development of production fish
9506300	Yakima/Klickitat Monitoring & Evaluation Program	Collaborate on the design and analysis of production fish in Cle

		Elum Hatchery
9506406	Monitoring of supplementation response variables for YKFP	Monitor physiology of fish in Cle Elum Hatchery
9305600	Assessment of captive broodstock technology	Collaborate by evaluating smoltification of experimental groups of spring chinook salmon.

Section 4. Objectives, tasks and schedules

Objectives and tasks

Obj. 1,2,3	Objective	Task a,b,c	Task
1	Manipulate growth rates of spring chinook salmon to correspond to patterns seen in wild fish.	a	Design study, sample, analyze data on physiology of juvenile salmon.
		b	Compare smolt-to-adult survival of experimental groups.
2	Conduct laboratory experiment on effects of varying growth rate on timing of smoltification of juvenile spring chinook salmon.	a	Sample fish, analyze data and publish results.
3	Evaluate physiology of juvenile spring chinook salmon in supplementation program.	a	Design study, sample, analyze data on physiology of juvenile salmon.
		b	Compare results with physiology of wild spring chinook salmon juveniles.

Objective schedules and costs

If you need more rows, press Alt-Insert.

Objective #	Start date mm/yyyy	End date mm/yyyy	Cost %
1	06/1998	05/ 2006	25%
2	06/1998	05/2000	30%
3	06/1998	05/2008	45%

Schedule constraints.

None anticipated

Completion date.

May 30, 2008

Section 5. Budget

FY99 budget by line item

Item	Note	FY99
Personnel		86,112
Fringe benefits		37,193
Supplies, materials, non-expendable property		$18,102
Operations & maintenance		$5,411
Capital acquisitions or improvements (e.g. land, buildings, major equip.)		
PIT tags	# of tags:	
Travel		$7,432
Indirect costs		$54,995
Subcontracts		$139,854
Other		
TOTAL		$349,099

Outyear costs

Outyear costs	FY2000	FY01	FY02	FY03
Total budget	$355,000	$358,000	$360,000	$363,000
O&M as % of total	2	2	2	2

Section 6. Abstract

Our overall goal is to reduce negative impacts of hatchery salmon on wild salmon and evaluate supplementation by 1) improving the smolt quality and smolt-to-adult recovery (SAR) of fish reared in hatcheries, and 2) producing a more wild-type hatchery smolt in supplementation programs. Items addressed in the 1995 FWP include 7.2D1,3,5; 7.3B.2,6,7,; 7.4K.1; 8.3c. High smolt quality is defined operationally as fish that migrate rapidly after release and survive to adulthood at relatively high rates. Rapid downstream movement after release reduces time for hatchery fish to interact and compete with wild fish. Fish that migrate rapidly downstream will not residualize and imprint on stream sites adjacent to the hatchery. Reduced residualism means less straying of adults on their homing migration and less breeding and genetic introgression with wild fish. Improving SAR of hatchery production fish will allow reduced numbers of juveniles released to realize the same number of adults contributed, and reduce impacts of hatchery on wild fish. Our previous research found correlations between smolt quality indices, spring growth rates, and SAR of spring chinook salmon in production hatcheries. Furthermore, we demonstrated that accelerating spring growth improved instream

migration of smolts. We also characterized the developmental physiology of wild chinook salmon in the Yakima River Basin. The experimental objectives of our proposed work include 1) improving SAR of the Columbia River terminal fishery by growth rate manipulation of juvenile salmon, 2) improving our understanding of how growth rate affects smoltification, 3) evaluate the physiology of salmon reared under conventional and natural-rearing systems in the supplementation program of the Cle Elum Hatchery (Yakama Indian Nation and WDFW).

Section 7. Project description

a. Technical and/or scientific background.

PROBLEM: It is perceived that hatchery-reared salmonids are of inferior quality and have lower smolt-to-adult survival compared to naturally reared salmon. Our research has shown that smolt quality of hatchery fish differs from that of wild fish in at least four aspects: size, growth rate, body fat, and dynamic physiological changes associated with smoltification. Our recent studies suggest that high growth rate during smolting stimulates downstream migration, but the impact of high growth rate on smolt-to-adult survival of hatchery-reared fish remains to be demonstrated. Although data are available on the physiology of wild spring chinook salmon juveniles, it is not clear that wild-like fish can be produced in captivity or whether hatchery production of wild-like fish would improve smolt-to-adult survival. In supplementation programs, it is critical that smolts are produced that have wild-like physiological attributes, yet the methods to produce wild-like smolts have not been established.

The objective of our research is to manipulate growth rates of hatchery reared fish to improve smolt quality, produce a more wild-type hatchery smolt, and accomplish the following goals:

1) Improve smolt-to-adult survival
2) Reduce interactions between wild and hatchery juveniles
3) Allow for the design of effective rearing programs for producing wild-like smolts in supplementation projects
4) Reduce straying and genetic introgression of hatchery fish on protected salmonid populations

This proposal addresses the Northwest Power Planning Council plan to "minimize genetic and ecological impacts of hatchery fish on wild stocks" as described in Phase One Amendments (Measure 2.4) to the Columbia River Basin Fish and Wildlife Program (adopted 14 August 1991). The major emphasis of this work will concentrate on assessing whether characteristics of smoltification and downstream migration of wild fish can be reproduced and applied to hatchery-reared fish. The proposal also addresses the NMFS Proposed Recovery Plan for Snake River Salmon (March 1995) Task 4.4 "Improve survival of Columbia River Basin anadromous salmonids by improving quality of fish released from hatcheries" and the goal to "Minimize impacts on listed salmon from interactions between Columbia River Basin hatchery salmon and natural salmon" (Task 4.3). The proposal also addresses FWP (1995) objectives to maximize post-release survival of hatchery fish (Section 7.2D1,3,5), evaluate supplementation programs

(Section 7.3B.2,6,7) including the Yakama program (Section 7.4K.1), and assist the development of terminal harvest fisheries (Section 8.3C).

Our studies on the quality of juvenile salmon produced by Columbia River hatcheries have indicated significant variation in timing and degree of smolt development among hatcheries. Most significantly, we found that differences in smolt development were positively correlated with smolt-to-adult survival (Dickhoff et al., 1995). These differences in smolt development and their relation to adult survival have implications regarding fish-rearing procedures and management of hatchery releases. One of the most significant findings of our studies of hatchery-reared chinook salmon is the positive relation between growth rate during the 2 months immediately preceding release and survival to adulthood. Furthermore, we have shown that increasing spring growth rate by experimental manipulation of spring chinook salmon improves their downstream movement (Beckman et al., 1996). This work suggests that accelerating growth rate of hatchery fish just prior to release may improve smolt quality and enhance downstream migration.

The linkage between growth rate, smoltification, seawater tolerance, and migration rate has been observed previously (Wagner et al. 1969, Varnavsky et al. 1992). Furthermore, it is compelling that such a link should exist, since the same hormones that control growth rate (growth hormone, insulin-like growth factor-I) also stimulate the development of seawater tolerance in salmonids (see Sakamoto and Hirano 1993 for review). Enhanced seawater tolerance is a characteristic attribute of successful smoltification (Hoar 1988).

In addition to our studies of hatchery salmon, we have studied wild juvenile spring chinook salmon in the Yakima River Basin. One of the rationales for the study of wild salmonids is that their physiology may serve as a template for improving hatchery rearing of salmon in production or supplementation programs. A better understanding of the physiology of wild fish should enable us to produce more wild-like fish in hatcheries. There are perceived differences in performance (migrational and smolt-to-adult survival) between wild/natural and hatchery-produced spring chinook salmon smolts, especially in the mid-and upper Columbia and Snake Rivers. Survival of hatchery smolts is generally lower than that of wild fish and hatcheries often have difficulty in procuring enough adults for brood stock. Furthermore, it is critical to produce smolts with physiological attributes of wild fish in supplementation programs (RASP 1992).

Results on wild spring chinook salmon juveniles indicate a dynamic pattern of physiological development (Dickhoff et al. 1997). In late autumn and early winter the wild fish reduce growth rate, feeding activity and metabolism. Wild fish lose substantial amounts of body fat over the winter in sharp contrast to hatchery reared salmon, which are generally obese (three to five times fatter than wild fish). In late winter and early spring, wild yearlings dramatically increase feeding, accumulate body fat, and resume growth. The sharp increase in growth of wild fish concomitant with smoltification is similar to the rapid growth of high quality smolts in hatcheries in our previous studies.. In summary, we can list several major differences in wild spring chinook salmon smolts compared to hatchery smolts:

1) Wild smolts are generally smaller than hatchery smolts of equivalent smolt-to-adult survival.
2) Wild fish show rapid growth rate (as assessed by plasma insulin-like growth factor I

(IGF-I) level) during the smolting period.
3) Wild smolts have less body fat than hatchery smolts.
4) Wild smolts show a more dynamic change in physiological and metabolic status from overwintering to the spring smolting period.
In controlled laboratory studies and in production-scale studies at Youngs Bay, OR and Cle Elum, WA, we propose to test the hypothesis that dynamic changes in growth and metabolism of juvenile salmon during winter/spring promote smoltification, improve the quality of hatchery-reared smolts, and promote rapid downstream migratory behavior. We will test whether seasonal growth rate manipulation patterned after wild fish produce dynamic changes in smolt physiology of spring chinook juveniles reared in captivity. To accomplish this we will impose a period of winter dormancy followed by accelerated spring growth. These growth rate manipulations should produce hatchery smolts that are similar to wild fish in size, growth rate, body fatness, and physiological smolt characteristics.

b. Proposal objectives.

1. Manipulate growth rates of spring chinook salmon to correspond to patterns seen in wild fish. Determine whether winter dormancy and high growth rate during smolting improves smolt-to-adult survival of spring chinook salmon released from net pens in the Columbia River terminal fisheries project (BPA project #9306000).
The hypothesis is: Growth patterns of wild fish can be reproduced on a hatchery production scale and will improve smolt-to-adult survival.
Products from this study will include BPA reports and peer-reviewed publications. The work is being done at a production facility, so technology transfer is assured.

2. Conduct laboratory experiments to determine the influence of growth rate on smoltification using the same genetic stock of chinook salmon as in objective 1.
The hypothesis is: There are minimal and maximal growth rates of juvenile spring chinook salmon that will produce smoltification in the summer, fall, or spring. This work is in collaboration with the captive broodstock technology assessment (BPA project # 9305600), which involves a diet ration experiment creating different growth trajectories for spring chinook salmon. The goal of the captive broodstock experiment is to determine how growth rate affects reproductive maturation. Our proposed collaboration would be to use the same experimental groups to assess growth rate effects on smoltification. Products will be the identification of minimal and maximal growth rates for implementation in production scale studies. Results will be published as BPA reports and in the peer-reviewed literature.

3. Advise on design, evaluate rearing protocols, and monitor smolt quality of spring chinook salmon juveniles in the optimal conventional treatment (OCT) and semi-natural treatment (SNT) rearing systems in the Cle Elum supplementation hatchery program (BPA projects # 956300 and 9506406). The hypothesis to be tested is: hatchery-reared fish can be raised to show wild-like physiological characteristics using OCT or SNT rearing protocols. The objective will be to evaluate the quality of smolts in the supplementation program by their physiological attributes, which will be compared to

wild and hatchery fish. Results will be published as BPA reports and in the peer-reviewed literature. Technology transfer will be assured since we will be working with hatchery manager.

c. Rationale and significance to Regional Programs.

The rationale of our studies is that methods of rearing spring chinook salmon in hatcheries may be modified or manipulated in order to promote physiological development and behavior similar to that found in wild fish. These modifications may result in improved performance characteristics for hatchery fish while minimizing impacts of hatchery fish on wild fish. The results will apply to both production and supplementation hatcheries. A large number of supplementation hatcheries have begun operating within the Columbia River Basin. Our proposed work in the Yakima Fisheries Project will characterize the physiological development of supplementation fish starting with the first group of fish to be reared and released. This is a unique opportunity for research, since we have the largest and most comprehensive database on the physiological development of juvenile salmon in hatcheries and in the wild. Rather than being limited to rely on post-release performance (survival, reproductive success), our physiological data can be used to assess pre-release success in achieving the target of producing a wild-like supplementation smolt. This information can be used to refine rearing protocols to improve post-release performance.

d. Project history

Project # 9202200. The project began in 1992 with selection of collection sites in the Yakima River Basin and standardization of collection methods. Wild fish sampling began in 1993 and continued through 1995. Sample and data analysis of wild fish samples began in 1994 and continued through 1997. Studies testing growth manipulation and the relationship between high spring growth rate and smolt-to-adult survival was initiated in 1997. Discussions on collaborative research with WDFW and YIN on assessing supplementation fish at the Cle Elum hatchery began in 1997.
Major results achieved include:
1. Characterization of physiology of wild spring chinook salmon, which differ significantly from hatchery reared fish.
2. Demonstration of the relationship between high growth rate, smoltification and downstream migration.
Publications:
Dickhoff, W.W., B.R. Beckman, D.A. Larsen, C.V.W. Mahnken, C.B. Schreck and W.S. Zaugg. 1995. Smolt quality assessment of hatchery-reared spring chinook salmon in the Columbia River basin. AFS symposium, 15:292-302.
Beckman, B.R., D.A. Larsen, B. Lee-Pawlak, and W.W. Dickhoff. 1996. Physiological assessment and behavior interaction of wild and hatchery juvenile salmonids: The relationship of fish size and growth to smoltification in spring chinook salmon. Annual report to the Bonneville Power Administration Project 92-022. October 1996.
Dickhoff, W.W., B.R. Beckman, D.A. Larsen, C. Duan and S. Moriyama. 1997. The role of growth in the endocrine regulation of salmon smoltification. Fish Physiol.

Biochem. 17:231-236.
Dickhoff, W.W., B.R. Beckman, D.A. Larsen and B. Lee-Pawlak. 1997. Physiology of migration in salmonids. Mem. Fac. Fish. Hokkaido Univ. 44:14-16.
Beckman, B.R., D.A. Larsen, S. Moriyama, B. Lee-Pawlak and W.W. Dickhoff. 1998. Environmental modulation of the growth hormone - insulin-like factor-I endocrine axis and its relation to size, growth and smoltification in juvenile spring chinook salmon (*Oncorhynchus tshawytscha*). Gen. Comp. Endocrinol. (submitted - June 97 in press Nov 97)
Beckman, B.R., D.A. Larsen, B. Lee-Pawlak and W.W. Dickhoff. 1998. The relationship of fish size and growth rate to migration of spring chinook salmon (*Oncorhynchus tshawytscha*) smolts. North American Journal of Fisheries Management (resubmitted Oct 1997)
Beckman, B.R. and W.W. Dickhoff. 1998. Plasticity of smoltification in spring chinook salmon (Oncorhynchus tshawytscha): Relation to growth and insulin-like growth factor-I. J. Fish Biology (submitted)
Years underway: 5
Past costs: $1,752,150

e. Methods.

A project is proposed with the following goals: 1) continue experiments manipulating growth rates of spring chinook salmon in the Columbia River terminal fishery project in Youngs Bay OR (BPA project #9306000), 2) continue controlled laboratory experiments on the effects of feeding on growth rate and smolt quality (in collaboration with BPA project # 9305600), 3) evaluate spring chinook salmon in supplementation project in Yakima River Basin (BPA projects #956300 and 9506406).

Element 1. Manipulate growth to improve smolt development of spring chinook salmon in the Columbia River terminal fishery.

Experiments will be conducted to test the hypothesis that winter dormancy followed by accelerated spring growth rate will improve smolt quality and smolt to adult survival on a production scale.

Spring chinook salmon will be obtained in November from Gnat Creek Hatchery, marked with coded wire tags (CWT) and placed in net pens in Youngs Bay, OR. Fish will be fed rations of Biodiet (Bioproducts, Warrenton OR) either on a standard schedule or a restricted schedule to reduce winter growth. The standard ration will be according to the feed manufacturer=s recommendation adjusted for water temperature. Fish will be fasted from December 1 to mid-January (winter dormancy). Maintenance rations of approximately 0.3% body weight per day will be fed from mid-January to mid-February. Accelerated growth of the fish on the wild fish growth profile will be accomplished by increasing the ration in mid-February to 1 to 2% body weight per day, depending on results obtained from the 1996-7 study. Control fish will be fed on standard rations (Bioproducts recommendation) from November to the release date of April 1 to achieve the target release size (40g).

Sampling protocol Fifteen fish from each group on each sampling date will be killed to

determine seasonal changes in selected physiological variables. Fish will be weighed and measured, and blood will be collected. Coloration will be noted on a three-point scale (1 = parr, 2 = transitional, 3 = smolt). General health (presence or absence of lesions), sex, and gonadal development will be noted. Blood samples will be used to determine hematocrit; the separated plasma fraction will be used to determine insulin-like growth factor-I and insulin levels (volume permitting). Gill tissues will be collected for determination of Na^+-K^+ ATPase activity. Remaining fish carcasses will be utilized for determining total body lipid. Fish will be sampled once in February and twice in March to determine seawater tolerance and preference at Oregon State University, using the behavioral chamber that has been developed in Corvallis, OR.

Sample analysis Samples will be analyzed for ATPase activities as described in Zaugg et al. (1991) and for plasma IGF-I as described in Moriyama et al. (1995), and results will be compared to known patterns of change in laboratory and hatchery-reared chinook salmon. Adult survival of released fish will be determined by CWT returns. It is anticipated that slow growth of fish in winter coupled with accelerated growth of fish in spring will improve smolt quality and smolt-to-adult survival. Graduate students and technicians from the University of Washington will assist in sample analyses.

Anticipated results: We anticipate that physiological development of fish reared on the wild fish growth pattern should show equal or better performance than the control group based on adult return rates. Critical uncertainty revolves around the best method to impose the winter dormancy and accelerated spring growth. How long should the fish be fasted? When should the refeeding period begin? Should the fish be given a maintenance diet during the winter? Is body fat and general health a good index to determine whether the fasting period has compromised fitness or produced chronic stress?

Element 2: Laboratory experiments on the effects of growth rate on smoltification of spring chinook salmon.

Spring chinook salmon (25,000 eyed eggs, Brood Year 1997) from the Willamette stock will be reared in controlled laboratory conditions on six dietary rations in order to produce six different rates of growth. The highest ration (100%) will be determined by the amount of food that the fish will consume. The remaining groups will be fed 90%, 80%, 70%, 60% and 50% of the maximal ration. It is anticipated that the 50% ration will be near maintenance level. Feeding will begin in February 1998 and continue through 1999. This experiment is designed to assess the effects of growth rate on reproductive maturation as part of a captive broodstock research program (BPA project # 9305600). We propose to take advantage of this ongoing experiment to assess the effects of growth rate on smoltification. Beginning in June 1998 we will sample twelve fish from each group and assess smolt morphology, gill Na-K ATPase activity and blood plasma levels of growth regulatory hormones (IGF-I, growth hormone and insulin). We will be particularly interested in determining fall and spring smoltification patterns.

Expected results: We anticipate that fish grown on the highest ration will have high rates of precocious reproductive maturation and/or go through smoltification in the fall instead of the spring. Several of the intermediate rations should produce fish that do not smolt in the fall but will show good smolt physiology in the spring and have low rate of precocious male maturation. These intermediate growth rate trajectories will be used to

identify size limits for rearing protocols for spring chinook salmon in production and supplementation hatcheries.

Element 3: Advise on design, evaluate rearing protocols and monitor smolt quality of spring chinook salmon juveniles in the optimal conventional treatment (OCT) and semi-natural treatment (SNT) rearing systems in the Cle Elum Supplementation Hatchery program. Beginning in June 1998 we will sample 12 fish from each group and assess smolt morphology, , body fat level, and blood plasma levels of growth regulatory hormones (IGF-I, growth hormone and insulin, volume permitting). Gill Na-K ATPase activity will be determined from January through April 1999. Monthly sampling will commence in June 1998 and then change to bi-monthly sampling in January 1999. Comparisons will be made of the physiology of fish grown in the OCT and SNT systems.

Expected results: We anticipate that we will find differences in the physiology of fish reared in OCT and SNT and in comparison with the patterns that we observe in wild spring chinook salmon juveniles in the Yakima River. The different physiological patterns will be used to modify or fine tune rearing protocols in the subsequent year.

f. Facilities and equipment.

Laboratory and data analyses and base of operations is the Northwest Fisheries Science Center of the National Marine Fisheries Service in Seattle, which is well-equipped to conduct the proposed studies. We have analytical balances, centrifuges, a gamma counter, ELISA plate readers, spectrophotometers, and chemical and radiation safety hoods. Modern fish rearing facilities available include a computer-operated closed recirculation system with biofiltration, ozonation and UV-radiation to maintain water quality. No additional equipment is requested. We have a van that is equipped with sampling gear, centrifuges and electric generator for field sampling at Youngs Bay terminal fisheries project and at the Cle Elum hatchery.

g. References.

Beckman, B.R., D.A. Larsen, B. Lee-Pawlak, and W.W. Dickhoff. 1996. Physiological assessment and behavior interaction of wild and hatchery juvenile salmonids: The relationship of fish size and growth to smoltification in spring chinook salmon. Annual report to the Bonneville Power Administration Project 92-022. October 1996.

Dickhoff, W.W., B.R. Beckman, D.A. Larsen, C.V.W. Mahnken, C.B. Schreck and W.S. Zaugg. 1995. Smolt quality assessment of hatchery-reared spring chinook salmon in the Columbia River basin. AFS symposium, 15:292-302.

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Hoar, W.S. 1988. The physiology of smolting salmonids. In: W.S. Hoar and D.J. Randall eds., Fish Physiology Vol. 11B. Academic Press, New York. pp. 275-344.

Moriyama, S., P. Swanson, M. Nishii, A. Takahashi, H. Kawauchi, W.W. Dickhoff and

E.M. Plisetskaya. 1994. Development of a homologous radioimmunoassay for coho salmon insulin-like growth factor-I. Gen. Comp. Endocrinol. 96**:**149-161.
RASP. 1992. Supplementation in the Columbia Basin, Summary Report Series, Final Report. Bonneville Power Administration, Project number 85-62.
Sakamoto, T. and T. Hirano. 1993. Expression of insulin-like growth factor I gene in osmoregulatory organs during seawater adaptation of the salmonid fish: Possible mode of osmoregulatory action of growth hormone. Proc. Natl. Acad. Sci. USA 90:1912-1916.
Varnavskiy, V.S., N.V. Varnavskay, S.V. S. Kalinin, and N.M. Kinas. 1992. RNA/DNA index as an indicator of growth rate of coho salmon (Oncorhynchus kisutch) during early marine life. J. Ichthyol. 32:10-19.
Wagner, H.H., F.P. Conte, and J.L. Fessler. 1969. Development of osmotic an ionic regulation in two races of chinook salmon *Oncorhynchus tshawytscha*. Comp. Biochem. Physiol. 29:325-341.
Zaugg, W.S., W.W. Dickhoff, B.R. Beckman, C.V.W. Mahnken, G.A. Winans, T.W. Newcomb, C.B. Schreck, A.N. Palmisano, B.M.Schrock, G.A. Wedemeyer, R.D. Ewing, and C.W. Hopley. 1991. Smolt quality assessment of spring chinook salmon. Bonneville Power Administration Project No. 89-046, Annual report, 109 p.

Section 8. Relationships to other projects

1. The proposed collaborative work with the Columbia River terminal fishery project in Youngs Bay OR (BPA project #9306000) is an opportunity for us to perform production-scale tests of our hypotheses on improving smolt quality by growth rate manipulation and patterning wild smolt development. The terminal fisheries project is a collaboration between Clatsop County Economic Development Council, and the Oregon and Washington Departments of Fish and Wildlife. Their on-going studies examine the time of release and smolt-to-adult (SAR) recovery of spring chinook salmon juveniles. Our proposed research will examine the quality of smolts released and modify growth rates of fish to improve efficiency and SAR. This terminal fishery has a high rate of adult return relative to upper river production programs. Thus, comparisons of SAR of experimental groups will be statistically robust. There is a substantial economy in research costs because of such a collaborative and mutually beneficial effort. The results of the proposed studies on rearing protocols can be expanded to include all spring chinook production hatcheries in the Columbia River Basin. Recently WDFW has requested our input on rearing protocols for their production and supplementation hatcheries.

2. The proposed controlled laboratory experiments on the effects of feeding on growth rate and smolt quality is in collaboration with BPA project # 9305600, which is an assessment of captive broodstock technology. The particular experiment is aimed at determining the effects of varying growth rate on the age of maturation of spring chinook salmon. This collaboration represents a substantial savings in research costs, since we will not need to duplicate the rearing of over 10,000 juvenile salmon. Furthermore, the scientific objectives of both studies can be expanded since we will be able to evaluate the interaction between smoltification rate and precocious maturation of males.

3. The proposed evaluation of spring chinook salmon in the supplementation project in Yakima River Basin (BPA projects #9506300 and 9506406) is a collaboration with the Washington Department of Fish and Wildlife and the Yakama Indian Nation. The proposed research is a logical next step to our previous work characterizing the physiology of wild spring chinook salmon in the Yakima River. We have provided our data on wild fish to WDFW and YIN biologists to aid them in designing rearing protocols for supplementation juveniles. This collaborative effort will provide the most complete evaluation of supplementation efforts available. The results should be applicable to all supplementation programs in the Columbia River Basin.

Section 9. Key personnel

Dr. Walton W. Dickhoff, Principal Investigator, will oversee progress on the project and be the primary manager of Objective 1. Approximately 30% time will be devoted to this project (supported by NMFS). He has worked on the physiology of salmon smoltification for over 20 years and is internationally recognized in this field.
Mr. Brian R. Beckman (Fishery biologist) is a co-Principal Investigator and primary project manager for Objectives 2 and 3. He will devote 100% time to the project. He has worked on smolt quality research for over 12 years, and has led the studies of wild smolt physiology.
Dr. Donald A. Larsen (Fishery biologist) is a co-Principal Investigator and project co-manager. He will devote 100% time to the project. He has participated in the research on smolt quality for 8 years.
Biographies:

Walton W. Dickhoff
Education
A.B. Biological Sciences, 1970, University of California, Berkeley.
Ph.D. Physiology, 1976, University of California, Berkeley.
Honors/Awards
U.S. Public Health Service Trainee, 1970-1974.
National Institutes of Health Fellowship, 1976-1977.
Tashiro Fellowship, Kitasato University, Japan, 1987.
Research Faculty Fellowship, Univ. Washington, College of Ocean and Fishery Sciences, 1988.
Distinguished Research Award, Univ. Washington, College of Ocean and Fishery Sciences, 1991.
Employment

1993-1998	Director, Cooperative Education and Research Program (UW/NMFS)
1987-1998	Professor (WOT), School of Fisheries, University of Washington.
1982-98	Physiologist, National Marine Fisheries Service, Northwest Fisheries Research Center, Seattle.
1988-1989	Assistant Director, Aquaculture Division, School of

Fisheries, UW.

1984-1987 Research Associate, School of Fisheries, University of Washington.

1981, '82,'86 Lecturer, Dept. Zoology, University of Washington.

1977, '79, '80, '82 Acting Assistant Professor, Dept. Zoology, University of Washington.

1975-1984 Research Associate, Dept. Zoology, University of Washington.

1974-1975 Research Assistant, Dept. Physiology/Anatomy, University of California, Berkeley.

Professional Activities

Professional Memberships:

American Association for the Advancement of Science, Society of Intergrative and Comparative Biology (former American Society of Zoologists; Chair, Divison of Comparative Endocrinology 1993-96), Endocrine Society

Editorships:

Member of Editorial Board of General and Comparative Endocrinology 1978-1991.

Acting Editor-in-Chief of General and ComparativeEndocrinology in 1979-84.

Selected publications:

Dickhoff, W.W., B.R. Beckman, D.A. Larsen, C. Duan and S. Moriyama. 1997. The role of growth in the endocrine regulation of salmon smoltification. Fish Physiol. Biochem. 17:231-236.

Dickhoff, W.W., B.R. Beckman, D.A. Larsen, C.V.W. Mahnken, C.B. Schreck, C. Sharpe and W.S. Zaugg. 1995. Smolt quality assessment of hatchery-reared spring chinook salmon in the Columbia River basin. AFS Symposium 15:292-302.

Dickhoff, W.W. 1993. Hormones, Metamorphosis and Smolting. In: The Endocrinology of Growth, Development, and Metabolism in Vertebrates. M.P. Schreibman, C.G Scanes, and P.K.T. Pang, eds. Academic Press, Inc., San Diego, CA pp. 519-540.

Dickhoff, W.W., C.V.W. Mahnken, F.W. Waknitz, W.S. Zaugg, M.G. Bernard and C.V. Sullivan. 1989. Effect of temperature and feeding on smolting and seawater survival of Atlantic salmon (*Salmo salar*). Aquaculture 82:93B102.

Folmar, L. C. and W.W. Dickhoff. 1980. The parr-smolt transformation (smoltification) and seawater adaptation in salmonids. A review of selected literature. Aquaculture 21:1-37.

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Education

B.S. (Biology) 1983, Oregon State University

M.S. (Marine Environmental Science) 1985, State University of New York at Stony Brook

Ph.D. Candidate 1992 - present, University of Washington

Work Experience

9/92 - present	Fishery Biologist; NMFS Montlake Laboratory
5/87 - 9/92	Fishery Biologist, NMFS Cook Field Station
3/86 - 5/87	Biological Technician , NMFS Cook Field Station
9/83 - 6/85	Graduate Assistant, SUNY Stony Brook

Honors/Awards

Unit Citation ESA Petitions	1992
Oustanding Performance	1989, 1990, 1993, 1994, 1996

Selected publications

Beckman, B.R. and W.S. Zaugg. 1988. Copper intoxication in chinook salmon (*Oncorhynchus tshawytscha*) induced by natural spring water: effects on Gill Na/K ATPase, hematocrit, and plasma glucose. Can. J. Fish Aquat. Sci., 45:1430 - 1435.

Beckman, B.R. and W.S. Zaugg. 1990. Effects of Actinomycin-D on Gill Na/K ATPase activity in freshwater and seawater adapted juvenile chinook salmon. J. Fish Biology: 37:907-911.

Zaugg W.S. and B.R. Beckman. 1990. Saltwater induced decreases in weight and length relative to seasonal ATPase changes in coho salmon (*Oncorhynchus kisutch*): a test for saltwater adaptability. Aquaculture 86:19 - 23.

Beckman, B.R., Larsen, D.A., Lee-Pawlak, B. , Moriyama, S., and W.W. Dickhoff. in press. Insulin-like growth factor-I and environmental modulation of growth during smoltification of spring chinook salmon, (*Oncorhynchus tshawytscha*). General and Comparative Endocrinology (in press).

Beckman, B.R., D.A. Larsen, B. Lee-Pawlak and W.W. Dickhoff. The Relation of fish size and growth rate to migration of spring chinook salmon smolts. North American Journal of Fisheries Management. (in press)

Donald A. Larsen

EDUCATION

B.A., Biology, University of Colorado, Boulder, CO. 1986.
M.S., Biology, Western Washington University, Bellingham, WA. 1990.
Ph.D., Fisheries, University of Washington, Seattle, WA. 1997.

PROFESSIONAL EXPERIENCE

3/92-Present	Fisheries Biologist GS-9, Integrative Fish Biology Program, Resource Enhancement and Utilization Technologies Division, Northwest Fisheries Science Center, Seattle, WA.
5/90-3/92	Biological Technician GS-7 (Fisheries), Integrative Fish Biology
3/90-5/90	Biological Technician (Fisheries): Foreign and Domestic Fisheries
3/88-12/89	Teaching Assistant, Biology Department, Western Washington
5/87-8/87	Foreign Fisheries Observer: National Marine Fisheries Service,

PUBLICATIONS

Dickhoff, W.W., Beckman, B.R., Larsen, D.A., Duan, C., and Moriyama, S. (1997). The role of growth in endocrine regulation of salmon smoltification. Fish Phys. and Biochem. 17:231-236.

Moriyama, S., Swanson, P. Larsen, D.A., Miwa, S., Kawauchi, H., and Dickhoff, W.W. (1997). Salmon thyroid stimulating hormone (TSH): Isolation, characterization, and development of a radioimmunoassay. Gen. Comp. Endocrinol. 108:457-471.

Larsen, D.A. and Swanson, P. (1997). Effects of gonadectomy on plasma gonadotropins I and II in coho salmon (*Oncorhynchus kisutch*). Gen. Comp. Endocrinol. 108, 152-160.

Larsen, D.A., Dickey, J.T., and Dickhoff, W.W. (1997). Quantification of salmon a- and thyrotropin (TSH) b-subunit messenger RNA by an RNase protection assay: Regulation by thyroid hormones. Gen. Comp. Endocrinol. 107, 98-108.

Dickhoff, W.W., Beckman, B. R., Larsen, D. A., Mahnken, C. V. W., Schreck, C. B., Sharpe, C, and Zaugg, W. S. (1995). Quality assessment of hatchery-reared spring chinook salmon smolts in the Columbia River Basin. 292-302. *In* H. L. Schramm and R. G. Piper ed. Uses and Effects of Cultured Fishes in Aquatic Ecosystems. Bethesda, Maryland, American Fisheries Society.

Dittman, A.H., Quinn, T.P., Dickhoff, W.W., and Larsen, D.A. (1994). Interactions between novel water, thyroxine and olfactory imprinting in underyearling coho salmon (*Oncorhynchus kisutch*, Walbaum). *Aquaculture and Fisheries Management.* 25:2, 157-169.

Section 10. Information/technology transfer

The results of the research will be published in BPA reports and in peer-reviewed scientific journals. The investigators will continue to present results at workshops, and scientific meetings at the regional, national and international levels. For example, during 1997 results of our present project were presented at the annual meeting of the American Fisheries Society (San Francisco, CA), the smoltification workshop (Hood River, OR), chinook salmon hatchery managers workshop (Pendleton, OR), natural rearing systems workshop (Port Ludlow, WA), and the Northwest Fish Culture Conference (Newport, OR). Since much of the work is done at production facilities, transfer of technology is assured.